Spatial pattern of dominant tree species of the secondary monsoon rain forest in Lianjiang, Guangdong Province

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Abstract: Based on the summed dominance ratios of species in sample plots, the first three dominant species (*Litchi chinensis*, *Elaeocarpus sylvestris* and *Canarium album*) of the secondary monsoon rain forest of Mt. Royal Shoe in Lianjiang City, western Guangdong, were chosen for analyzing their spatial distribution pattern with the analysis methods such as frequency models of Poisson Distribution, Two Negative Items Distribution, Neyman Distribution, aggregate indexes, Taylor exponential equation and Iwao's equation modeling. The results showed that these three species distributed in the congregate spatial pattern. *Litchi chinensis* and *Elaeocarpus sylvestris* had the characteristic of basic congregate population and attractive characteristic between their plants. The patterns for *Canarium album* may change and become more evenly distributed with the increase of density. The overall species spatial pattern also depended on the conservation of the secondary monsoon rain forest besides it was affected by the species reproduction characteristics and its growing environment. The congregate spatial patterns of three dominant species showed that it is important to conserve forest urgent conservation of the forest.
Key words: Secondary monsoon rain forest; Spatial pattern; Summed dominance ratio; Aggregate index
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Introduction

In the tropical southern China, large area of the climax vegetation once distributed there, namely the tropical rain forest, but the area had decreased astonishingly (Zhou *et al.* 1996; Zen *et al.*1997). The kind of vegetation was not left in Leizhou Peninsula because of frequent interference of man's cutting activities and agricultural exploitation. Therefore, it is highly significant to carry out ecological studies on the several left patches of the secondary tropical monsoon rain forests in this area so as to understand their species components, structure and development of the plant associations. Spatial pattern analysis has become one of researches of population ecology (Krebs 1978; Peng 1989; Wang 1998). And we didn't find any research reports about the secondary monsoon rain forest in the north tropics. The spatial pattern analysis of tropical rain forest species offers better protection strategy about the north-tropical rain forests. The spatial patterns of dominant species also provide technical bases for setting up of a natural reserve to conserve the rare vegetation, especially for endangered plant populations in the forest.

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Sites

Our research area is located at Mt. Royal Shoe, about 6 km east to Lianjiang City, Guangdong, with latitude 21°36′ and longitude 110°20′ and total area about 60 hm^2. The mountain has only two tops. The forest laterite originated from underneath volcanic rocks has high contents of organic material with pH 4.5-5.5 and the detritus about 3 cm thick. In sample plot annual mean temperature is 23.5 °C and mean annual precipitation is 1 758.8 mm.

According to the local records, Mt. Royal Shoe was the most important original genetic area for *Litchi chinensis*. The secondary monsoon rain forest at Mt. Royal Shoe was regenerated after the cutting down of trees in 1958. The age of the arbor layer trees should be about 10-50. There were 14 fern species, only 1 species (*Gnetum montanum* Markgr.) of Gymnospermae and 325 species of Angiospermae. The height of forest crown was about 12-16 m. The covering rate of arbor layer was 0.70-0.95. There were totally 47 arbor species among the arbor layers and the main species were as following: *Litchi chinensis* Sonn., *Canarium album* (Lour.) Rauesch., *Elaeopcarpus sylvestris* (Lour.) Poir, *Cinnamomum camphor* (L.) Presl, *Canarium pimela* Leenhoust, *Sapium discolor* (Champ. ex Benth.) Muell.-Arg., *Meliosma fordii* Hemsl., *Ormosia semicastrata* Hance, *Syzygium buxifolium* Hook. et Arn., *Symplocos hirta* (Hand.-Mazz.) Li, *S. summuntia* Buch, *Endospermum chinense* Benth., *Lannea coromandelica* (Houtt.) Merr., *Pithecellobium clypearia* (Jack.) Benth., *Evodia meliaefolia*

(Hance) Benth., *Lindera megaphylla* Hemsl., *L.glauca*(Sieb. et Zucc.) Bl., *Cratoxylum ligustrinum* (Spach) Bl., *Callicarpa kwangtungensis* Chun, *Horsfieldia amydalina* Warbg., *Antiaris toxicaria* (Pers) Lesch., etc.. There were 177 shrub species. In the shrub layer, there were few seedlings of the dominant arbor species. The commonly found shrub species were *Casearia glomerata* Roxb, *Dasymaschalon rostratum* Merr. et Chun, *Psychotria rubra* (Lour.) Poir., *Ardisia quinquegona* Bl., *Lasianthus chinensis* Benth., *Glochidion eriocarpum* Champ., *Flacourtia indica* (Burm.f.) Merr., *Evodia lepta* (Spreng.) Merr., *Styrax japonicus* Sieb. et Zucc., *Pseudosasa amabilis* (Mecl.) Keng. f., *Ardisia japonica* (Hornsted) Bl.). In the herbaceous layer, the height was at 1-1.5 m and shade coverage was at 5% or so, *Pandanus tectorius* Sol. prevailed over all other species; and other often-presenting herbaceous species were *Lophatherum gracile* Brongn., *Carex cryptostachys* Brongn and so on. There were 79 herbaceous species in the forest. The ferns were mainly *Adiantum capillus-veneris* L., *Colysis digitata* (Bak.) Ching, *Hemigramma decurrens* (Hook.) Cop., *Nephrolepis auriculata* (L.) Triman, *Pteris ensiformis* Burm., *Dicranopteris dichotoma* (Thunb.) Bernh., etc.. 24 vine species were recorded, and were mainly *Piper chinense* Miq., *Tetracera asiatica* (Lour.) Hoogl., *Smilax glabra* Roxb., *Millettia lasiopetala*(Hay.) Merr., *Byttneria aspera* Colebr., *Calamus egregius* Burret., *Lygodium microphyllum* (Lav.) R.Br., *Diploclisia glaucescens* (Bl.) Diels, etc..

Research methods

Plot survey

Among the secondary monsoon rain forest, 30 plots were set up evenly with each square area of 20 m×20 m. We recorded every tree's height and diameter at breast height, plant number of each species as well as the conditions of growing site.

Summed dominance ratio (S_{DR2})

The coverage ratio means the result of a species total section area at height of breast divided by all species section area at the same height in a plot.

$$S_{DR2} = (D+C)/2 \times 100\% \quad (1)$$

Where:

D-- Density ratio; *C*-- Coverage ratio.

The results of equation (1) (Li *et al.* 2000) produce all species S_{DR2} values with the input of the plot data. The first three largest values of the average species S_{DR2} are regarded as dominant species in further spatial pattern analysis.

Determination of spatial patterns

The data were treated with the frequency models of Poisson distribution, Two Negative Items Distribution and Neyman Distribution. The distribution pattern (Taulor 1984) was obtained with following methods.

Aggregate coefficients calculation (Pielou 1985; Krebs 1978; Taulor 1984):

Distribution coefficient (*C*):

$$C = S^2 / \overline{X} \quad (2)$$

Aggregate index (*I*):

$$I = S^2 / \overline{X} - 1 \quad (3)$$

Distribution index (I_σ):

$$I_\sigma = n(\sum X_i^2 - N)/\{N(N-1)\} \quad (4)$$

Cassie R.M.Index (C_A):

$$C_A = (S^2 - \overline{X})/\overline{X}^2 \quad (5)$$

Average clump index (X^*):

$$X^* = \overline{X} + S^2/\overline{X} - 1 \quad (6)$$

Iwao's equation:

$$X^* = \alpha + \beta\overline{X} \quad (7)$$

Taylor Index (lg*a*): as Taylor exponential equation is $S^2 = a\overline{X}^b$, then we obtain the value of lg*a* as followed:

$$\lg S^2 = \lg a + b\lg\overline{X} \quad (8)$$

Where:

X_i-- the number of plants of one species in No.*i* plot;

$\overline{X}$ -- the average number of plants of one species in all plots;

N --the total number of plants of one species;

S^2 –the square deviation of numbers of a species in all plots;

α, β --the linear constants between X^* and $\overline{X}$.

The judgment of spatial patterns of species could be figured out with above indexes as showed in Table 1. In equation (8), when lg*a*=0 and *b*=1, we can confirm that the species population is always congregate in any density; when lg*a*>0 and *b*>1; when lg*a*<0 and *b*<1, the spatial distribution becomes more and more evenly with the increasing of its density.

We grouped the data into 5 groups with data from 6 plots. In each group we obtained the spatial pattern by the Taylor exponential equation and Iwao's equation for the dominant species of the associations and then marked correlation with their ideal equations.

Table 1. Determination of spatial patterns of species

Spatial patterns	C	I	I_δ	C_A	$X^*/\overline{X}$	β
Random	$C=1$	$I=0$	$I_\delta=1$	$C_A=1$	$X^*/\overline{X}=1$	$\beta=1$
Even	$C=0$	$I<0$	$I_\delta<1$	$C_A<0$	$X^*/\overline{X}<1$	$\beta<1$
Congregate	$C>0$	$I>0$	$I_\delta>1$	$C_A>0$	$X^*/\overline{X}>1$	$\beta>1$

Results

Comparison of average S_{DR2} of the dominant species

According to the plot data, we chose the species with $S_{DR2} \geqslant 6\%$ in each plot to obtain the species average S_{DR2} in 5 plots, then we got the first three species with largest average S_{DR2}, which were *Litchi chinensis*, *Elaeocarpus sylvestris* and *Canarium album* recorded in Table 2. Therefore, those trees had dominated in the secondary monsoon rain forest of Mt. Royal Shoe. *Litchi chinensis* as the first main species dominated in 25 plots among 30 surveyed plots and *Elaeocarpus sylvestris* was investigated in 5 plots in the same way. They both had the characteristic of basic congregate population and attractive characteristic between their plants. *Canarium album* was an important companion species in the forest.

Spatial pattern of the populations of dominate species

Frequency modeling result of three dominant species showed that all these population's spatial patterns belonged to the model of Two Negative Items Distribution. Based on data of the 30 plots, we obtained aggregate indexes according to the equations of (2)-(7) as showed in Table 3. The values of Distribution Coefficient (C) of *Litchi chinensis*, *Elaeopcarpus xylvestri* and *Canarium album* all were more than 1 at the notable level of $X^2_{0.05}$ with X^2 test; their Aggregate Indexes (I) were all more than 0; and their Distribution Index (I_δ) all larger than 1 at the notable level ($F_0 > F_{0.05}$) of the random deviation test with formula as $F_0 = \{I_\delta(\Sigma X_i - 1) + n - \Sigma X_i\} / (n-1)$; $X^*/\overline{X}$ were over 1. So whichever aggregate index was marked, the spatial patterns of these three dominant species fit themselves into the model of Two Negative Items Distribution, namely congregate distribution. It was clear that both methods of aggregate indexes and comparison of frequency modeling reached the same result. We found that both methods could be applied to judge the spatial patterns of dominant trees in the secondary monsoon rain forest in north-tropical areas as important reference.

Table 2. Comparison of average S_{DR2} values of main species

Species	Average S_{DR2} (%)	Number of plots	$x\sigma_{n-1}$ of S_{DR2}
Litchi chinensis	52.59	30	23.40
Elaeocarpus sylvestris	27.13	12	13.76
Canarium album	21.00	18	9.35

Table 3. Aggregate indexes of spatial patterns for three main trees

Species	C	I	I_δ	C_A	$X^*/\overline{X}$	Spatial patterns
Litchi chinensis	9.1294	8.1294	1.2262	0.2336	1.2334	Congregate
Elaeocarpus sylvestris	7.9732	6.9732	1.7044	0.7254	2.4508	Congregate
Canarium album	5.2504	4.2504	1.6130	0.6304	1.6304	Congregate

In Table 4, both *Litchi chinensis* and *Elaeopcarpus sylvestris* ($\lg a>1$, $b>1$ and $\beta>1$) were congregate at all densities and correlated with their densities. *Canarium album* ($\lg a<0$ and close $=0$, $b>1$ and $\beta>1$) also means congregate distribution of its population. It is estimated that their species may become more evenly distributed with the increasing of its density.

Table 4. Modeling of Taylor exponential equation and Iwao's equation

Species	Taylor exponential equation		Iwao's equation	
	Equation	Correlated index	Equation	Correlated index
Litchi chinensis	$S_2=1.824\,3\,\overline{X}^{1.434\,1}$	$0.908\,2^{**}$	$X^*=6.961\,1+1.029\,2\,\overline{X}$	$0.915\,9^{**}$
Elaeocarpus sylvestris	$S_2=1.300\,8\,\overline{X}^{1.632\,8}$	$0.937\,6^{**}$	$X^*=0.945\,0+1.386\,5\,\overline{X}$	$0.925\,2^{**}$
Canarium album	$S_2=0.995\,2\,\overline{X}^{1.722\,7}$	$0.912\,8^{**}$	$X^*=-0.203\,5+1.481\,2\,\overline{X}$	$0.915\,3^{**}$

Notes: **--very notable (0.01) correlation between S^2 and $\overline{X}$ or X^* and $\overline{X}$.

Conclusions

The results that 3 dominant tree species in building the forest of Mt. Royal Shoe in Lianjiang, Guangdong met the spatial pattern of Two Negative Items distribution meant the wide applicability of this spatial pattern in depicting the distribution of species population (Wang 1998). The frequency comparison could not provide more information about the reasons in forming its spatial pattern.

Taylor exponential index and Iwao's equation gave more reasonable explanation on the spatial pattern of dominant species in the north-tropical secondary rain forest. *Litchi chinensis, Elaeopcarpus sylvestris* and *Canarium album* showed that they were congregate. Among them *Litchi chinensis* and *Elaeopcarpus sylvestris* were congregate at any density and correlated with their densities ; *Canarium album* (lg$a$<0 and close=0, b>1 and β> 1) also meant congregate of its spatial pattern, but it maybe become more evenly distributed with the increasing of its density.

All these three species bear heavy edible fruits that cannot be easily distributed evenly by the means of nature forces such as wind and water. This suggests that the different patches of the same species may have potential genetic diversity with its congregate population spatial pattern.

The spatial pattern of a population is affected by many factors, e.g. the diversity of forest, fruiting and seed distributing habit of species, and growing conditions as well as interference from man's activities (Hubbell *et al.* 1983). We did find and record a few of the seedlings and small plants. Thus, we are sure that the spatial pattern of trees in the north-tropical secondary monsoon rain forests was correlated with its conservation status besides other natural ecological proceeding factors.

The dominant species spatial patterns provide technical bases for conserving the rare vegetation, especially for the endangered species populations, such as *Litchi chinensis*, etc..

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